Requirements on the barrel alignment from the point of view of the resolution of the detectors

Let us consider all shifts and rotations that have effect on the measurement in Rφ plane. There are five:

- Shift across the ladder σ_d
- Shift in the radial ladder position σ_ρ
- Rotation in the ladder plane σ_Δ
- Rotation along "short" ladder axis σ_δ (different radii at active and passive bulkheads)
- Rotation along "long" ladder axis σ_γ (rotation along the beam line)

Assuming that all the angles are small, we can consider all of them independently. That gives:

$$\sigma_d = d$$

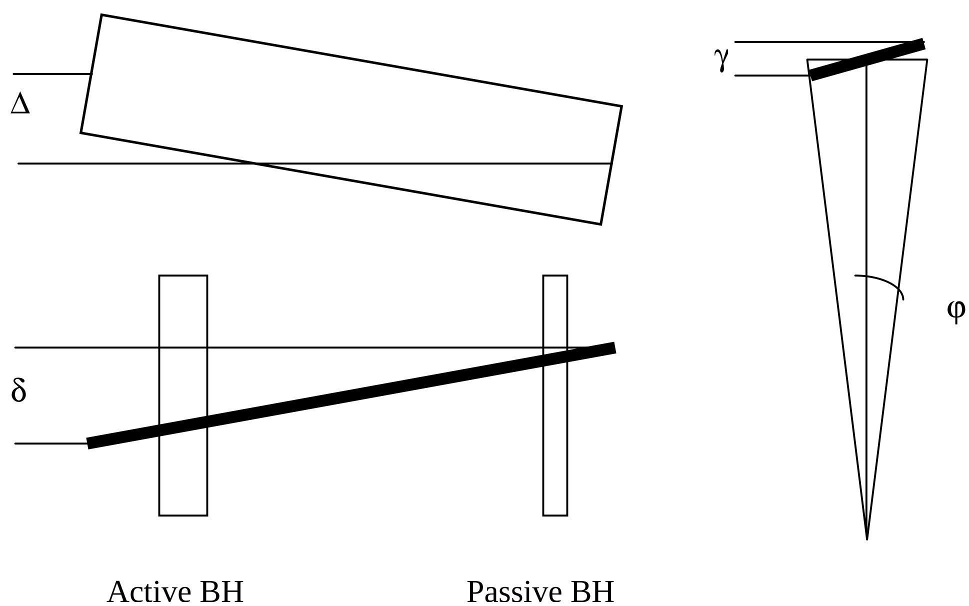
$$\sigma_\rho = \frac{\varphi}{\sqrt{3}}\rho \qquad = (0.15\div 0.08)\ \rho$$

$$\sigma_\Delta = \frac{\Delta}{\sqrt{12}} \qquad = 0.3\ \Delta$$

$$\sigma_\delta = \frac{\varphi}{4}\delta \qquad = (0.065\div 0.038)\ \delta$$

$$\sigma_\gamma = 0.15\varphi\cdot\gamma = (0.04\div 0.02)\ \gamma$$

where φ is a angular half width of the ladder (15^0 for layers 1 and 2 and 7.5^0 for outer layers), d is the transverse shift, ρ is the radial shift, and Δ, δ, γ characterize the rotations:



Now if the detector resolution is 10 microns, the combined error of the five should be less than that. Let's take σ_Δ, σ_δ, σ_γ, σ_d and $\sigma_\rho \leq 3$ μm. That gives

- $d \leq 3$ μm
- $\rho \leq 20 \div 40$ μm (layers 1,2 and 3,4 respectively)
- $\Delta \leq 10$ μm
- $\delta \leq 40 \div 80$ μm (layers 1,2 and 3,4 respectively)
- $\gamma \leq 75 \div 150$ μm (layers 1,2 and 3,4 respectively)

Note, that all the numbers stand for Gaussian dispersions. The precision observed so far with the TP method is about 4 microns in the ladder plane and better than 20 microns in the radial direction. It means that Gaussian dispersions for displacement measurements are

- $d \rightarrow$ 2.8 microns
- $\rho \rightarrow$ 10 microns
- $\Delta \rightarrow$ 6 microns
- $\delta, \gamma \rightarrow$ 30 microns

which is quite good. Adding these in quadrature gives a 4.6 micron error due to the imperfect knowledge of the alignment, which is negligible compared to the resolution.

Requirements on the barrel alignment from the point of view of the trigger.

Unlike the previous case, the constraints here are coming from the size of the beam spot (about 30 microns) and the fact that one can not correct for rotations on the trigger level, which makes constraints on the *placing* of the detectors rather than the quality of the survey.

It is a job of a trigger simulator to estimate the effects caused by misalignment of the silicon ladders. However, for an infinite momentum tracks (straight tracks without multiple scattering) one can easily calculate impact parameter from four measurements in the silicon. Let's consider a track at $\varphi=0$, i.e. along the x-axis. From the usual formula for fit to a straight line $y=kx+b$

$$b = \frac{<y><x^2> - <xy><x>}{<x^2> - <x>^2}$$

one gets ($y<<x$)

$$IP = \frac{\sum\limits_{i=1,4} y_i \left(\sum\limits_{j=1,4} R_j^2 - R_i \left(\sum\limits_{j=1,4} R_j \right)^2 \right)}{4 \cdot \sum\limits_{j=1,4} R_j^2 - \left(\sum\limits_{j=1,4} R_j \right)^2} = \sum_{i=1,4} y_i \cdot W_i$$

where R_i are the layer radii and y_i are the measurements (≡0 for ideal alignment). Weights W_i are easy to calculate:

Layer	Radius, mm	Weight		Radius, mm	Weight
1 inner	*28*	*1.136*			
1 outer				*36*	*1.007*
2 inner				*46*	*0.722*
2 outer	*55*	*0.448*			
3 average	*72*	*0.014*		*72*	*-0.021*
4 average	*95*	*-0.599*		*95*	*-0.707*

Note that outermost layer alignment is almost as important as the innermost. Layer 3 alignment is not critical. These features are partially due to the simplification of the model (infinite track momentum). The proper simulation is very important.

It is clear, however, that one should mount the ladders so that the related error is of the order of *10 microns* in the Rφ plane (that gives error in IP of less than 15 microns)

If one assumes that trigger software can take out both shifts *d* and ρ, than we have σ_Δ, σ_δ, and $\sigma_\gamma \leq 6$ μm. That gives (for innermost layer)

- $\Delta \leq 20$ μm $\Rightarrow$ 12 micron notch-to notch shift
- $\delta \leq 90$ μm
- $\gamma \leq 150$ μm

which is achievable. The requirement for δ seems to be the hardest to satisfy. If STT cannot adjust for radial placement at all this requires $\rho \leq$ 40 microns, which is more than twice less than had been achieved so far.

Summary

The hardest to meet are the trigger requirements, as the rotations of the ladders cannot be accounted for. The problem lies not in the transverse but in radial placement accuracy.
It is very desirable that STT could adjust for *both* transverse and radial shifts in ladder placement.

Though the most stringent requirements on the silicon alignment come from the offline tracking needs, a proper survey can meet the desired accuracy.